
foggy condition in Chi-Lan, Taiwan

TCCIP-TReAD資料應用於台灣雲霧帶微氣候韌性之研究

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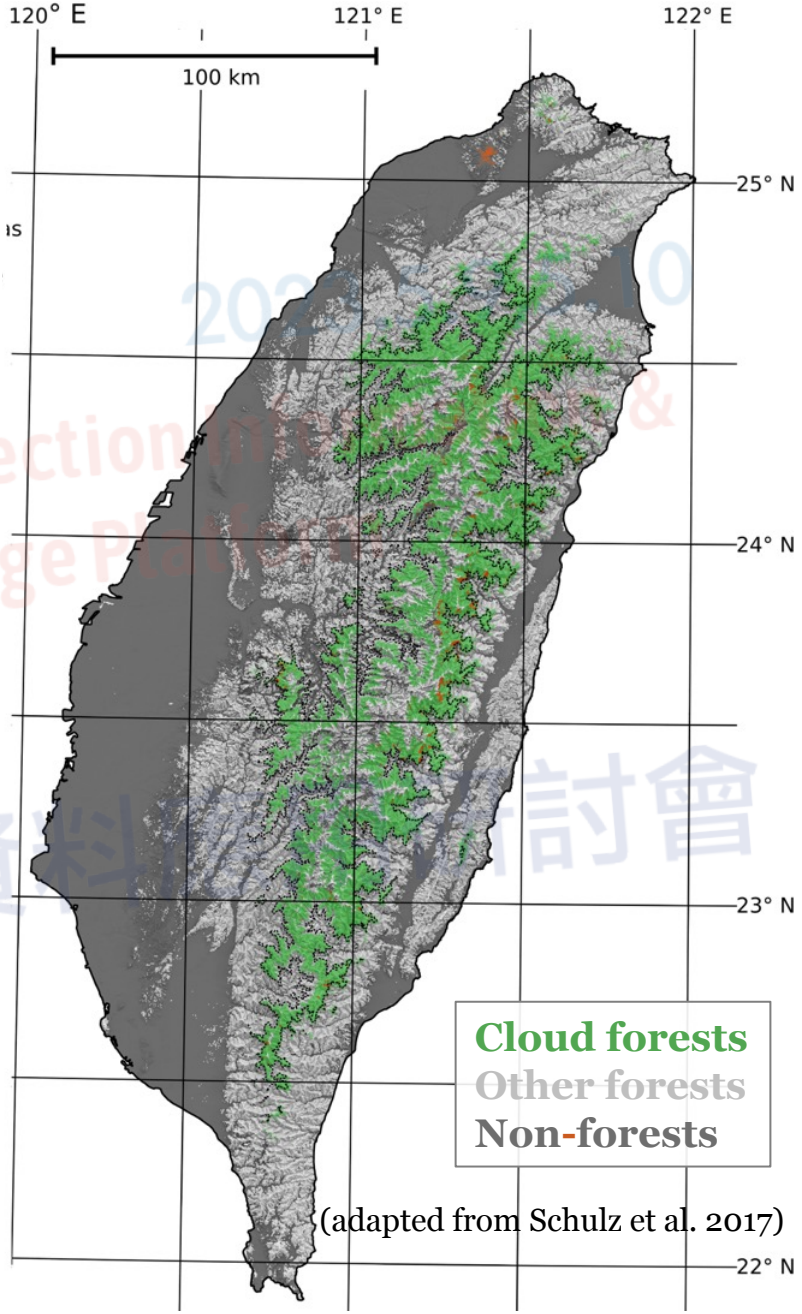
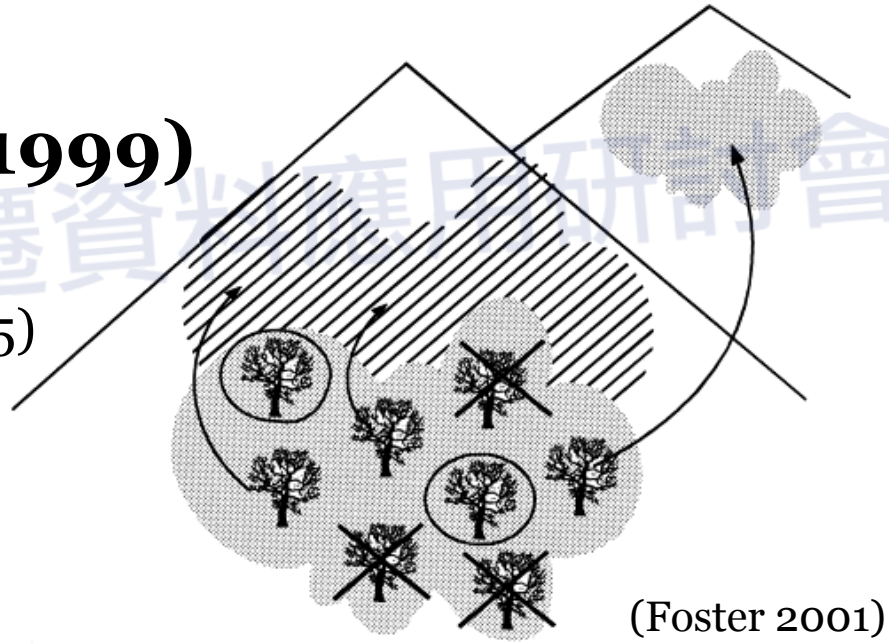


(adapted from Schulz et al. 2017)

HydroClimatology Group
at Department of Atmospheric Sciences, National Taiwan University

Climate change

1. **Changes in temperature and rainfall patterns**
   - **replacement of low-altitude ecosystems**
   - **species invasion**
   - **extinction of cloud forests on mountain peaks**
     (Foster 2001; Pauchard et al. 2009; Oliveira et al. 2014)
2. **Lifted cloud-base height (Still et al. 1999)**
   - **reduction of cloud/fog incidence**
     (Pounds et al. 1999; Nair et al. 2003; Williams et al. 2015)
   - **decline in species**
     (Pounds et al. 1999; Foster 2001; Oliveira et al. 2014)

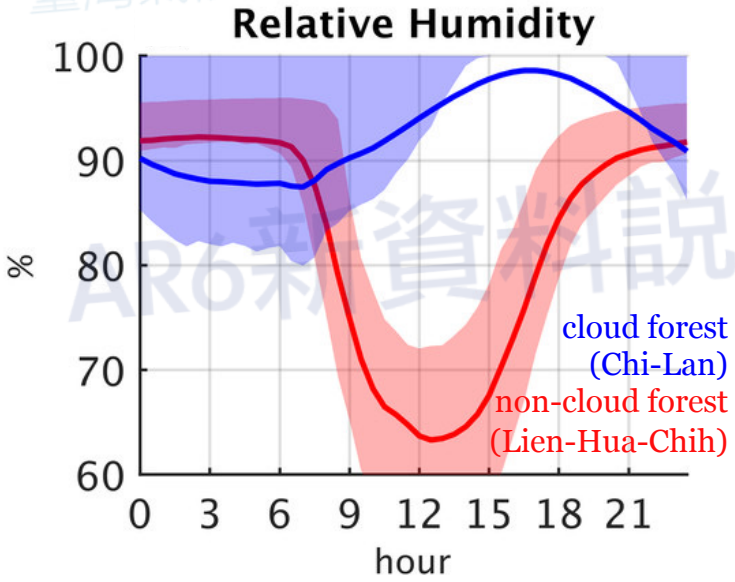


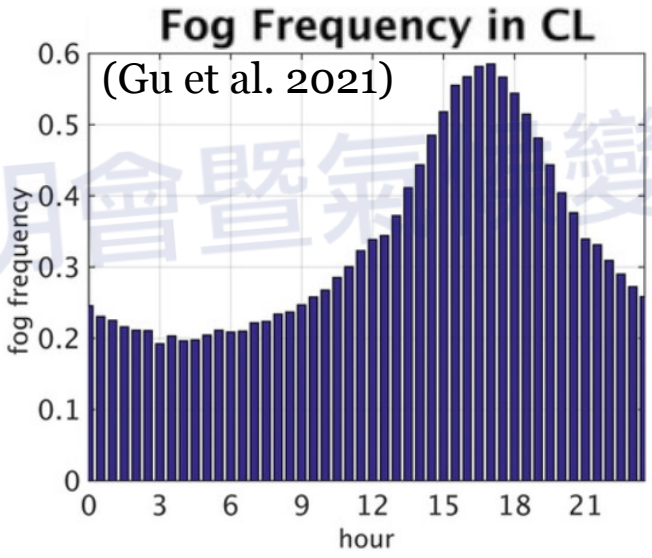
(Foster 2001)

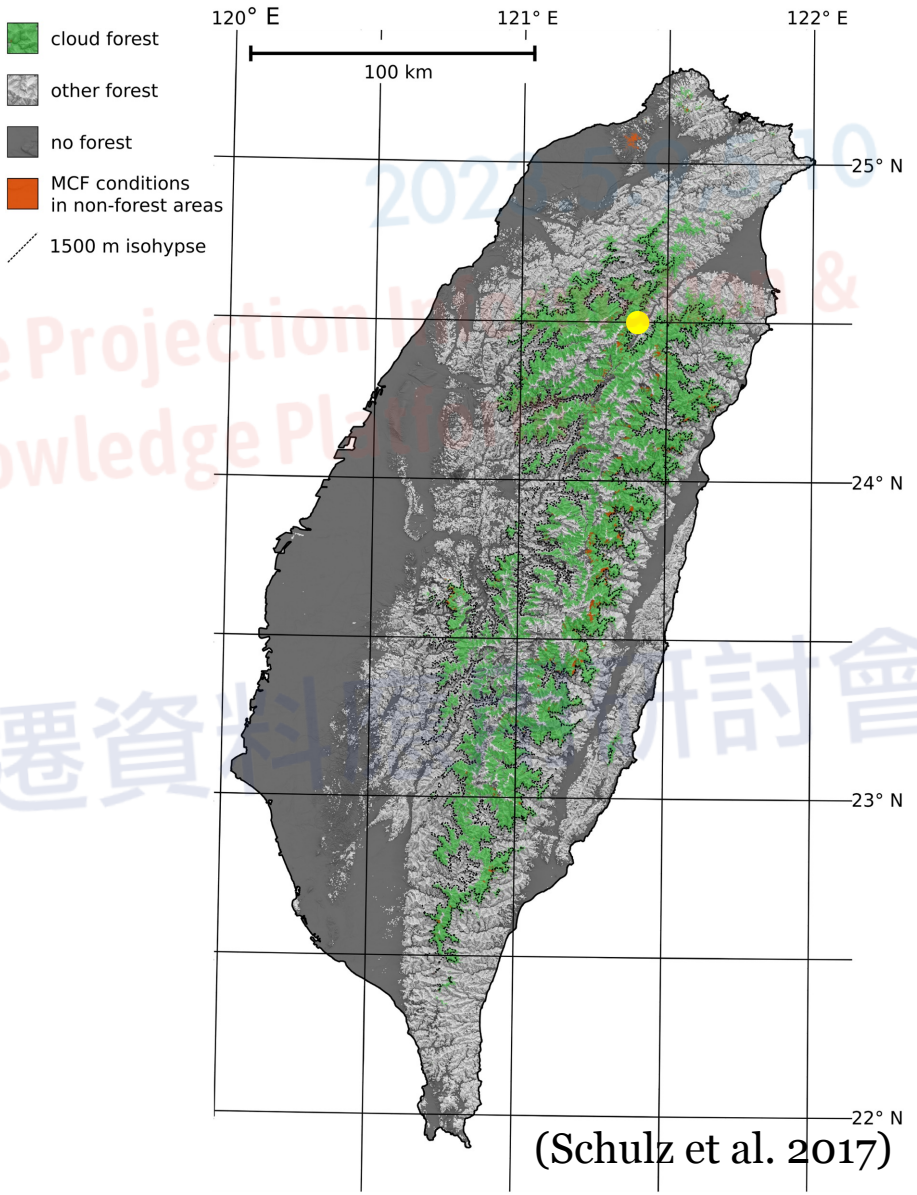
Relative humidity

Chi-Lan cloud forest (Gu et al. 2021):

- greatest relative humidity (RH) in the afternoon – highest fog frequency
- low temperature and high moisture supply in the daytime







(Schulz et al. 2017)

Knowledge Gaps

1. Mean state of RH:

Chi-Lan cloud forest (Gu et al. 2021)

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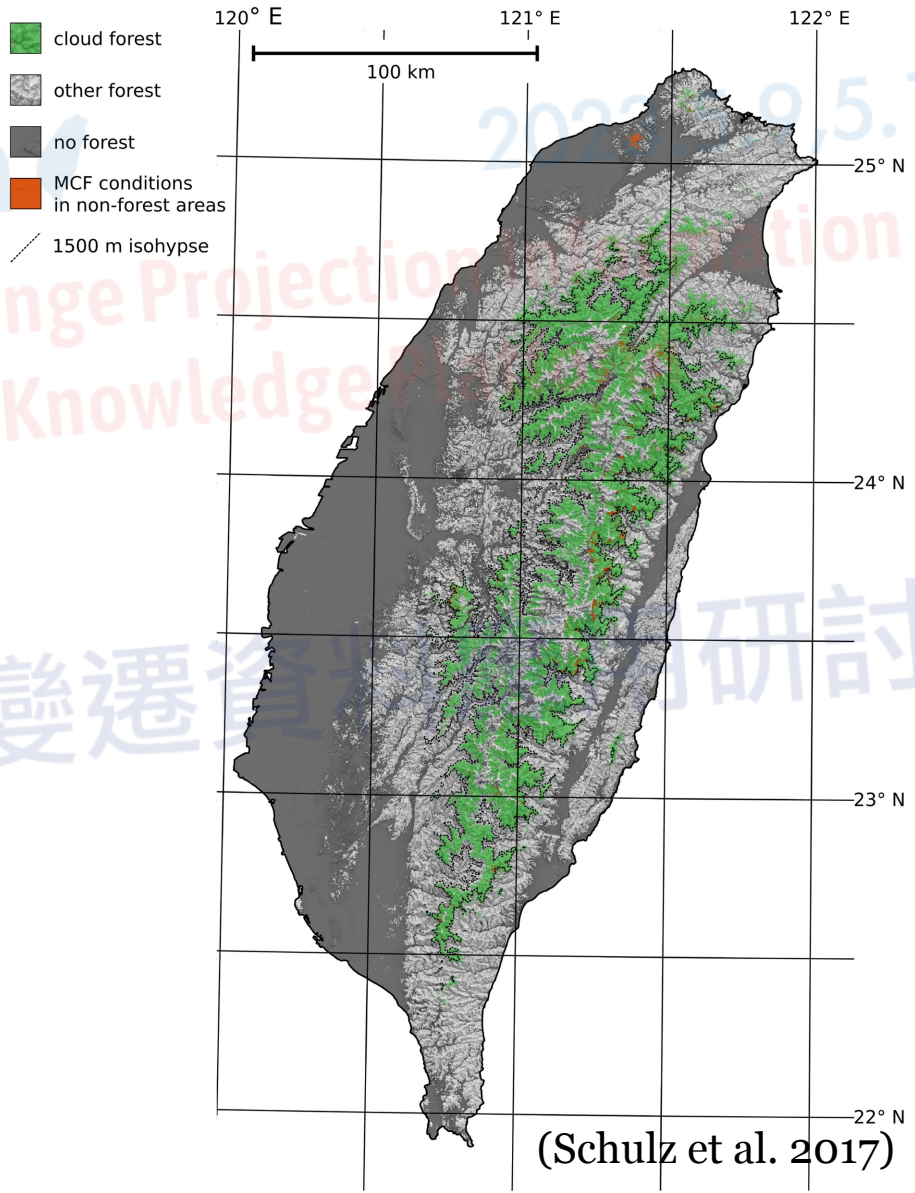
Cloud forests in Taiwan

2. Vulnerability in cloud forests :

- **Few studies discussed conditions in Taiwan**
- **Local changes between two time periods**



(Schulz et al. 2017)

Scientific Questions

1. Mean state of RH:

Chi-Lan cloud forest (Gu et al. 2021)

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Cloud forests in Taiwan

Mean state

Q1. How are cloud forests in Taiwan **different from non-cloud-forested regions** in their characteristics of relative humidity (RH)?

2. Vulnerability in cloud forests :

- **Few studies discussed conditions in Taiwan**
- **Local changes between two time periods**

Long-term variation

Q2. How did RH in cloud forests in Taiwan **change** in the past 42 years?

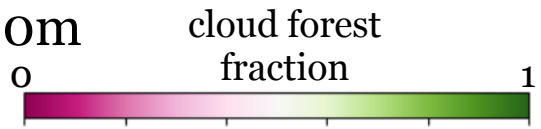
Data

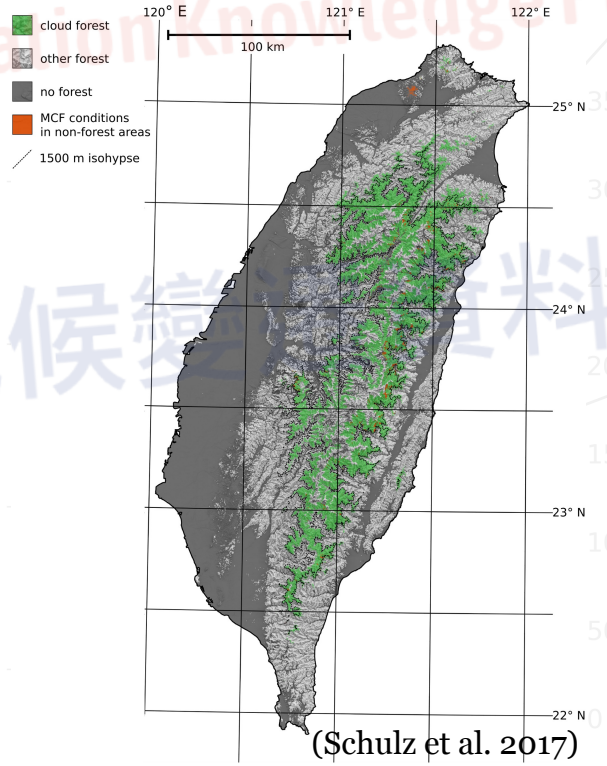
TCCIP-TReAD data

- 1980-2021 (42yrs); hourly
- Near-surface
  - Q (specific humidity)
  - T (temperature)
  - RH (relative humidity)
  - LH (latent heat fluxes)
  - precipitation
- Eastern Taiwan
  - 23-24.5 degN

Cloud forest mask from Schulz et al. 2017

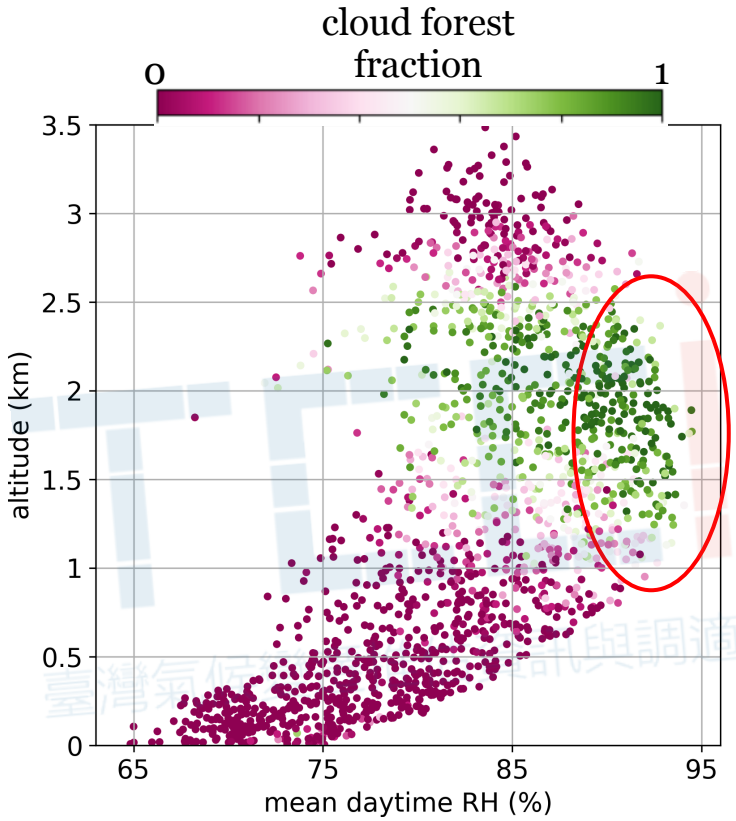
- spatial: Taiwan; 250m

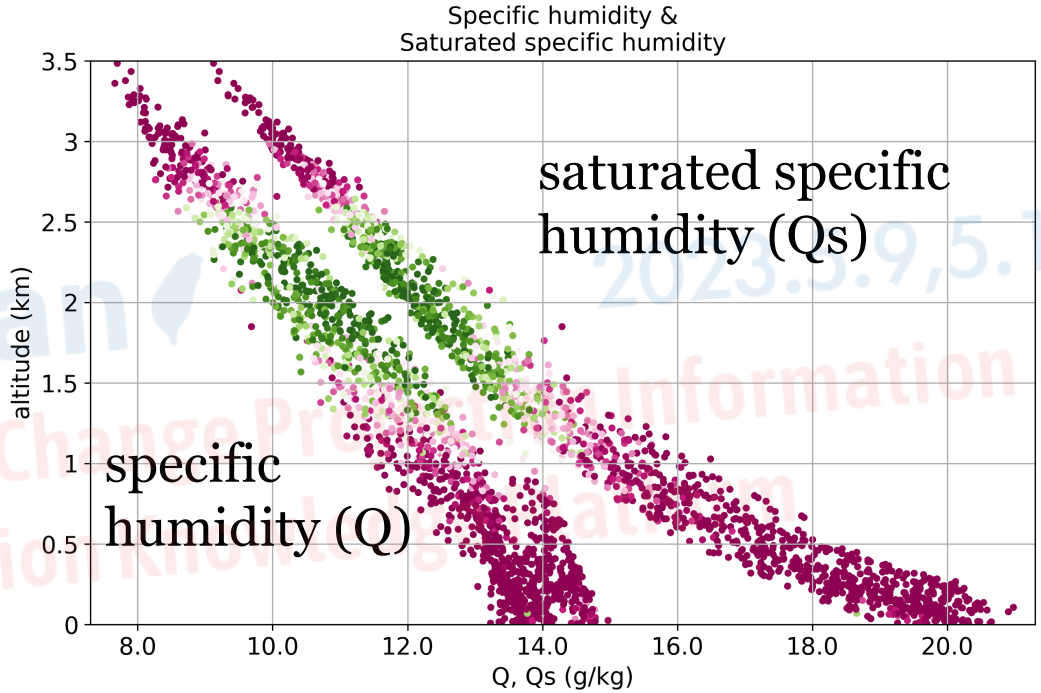




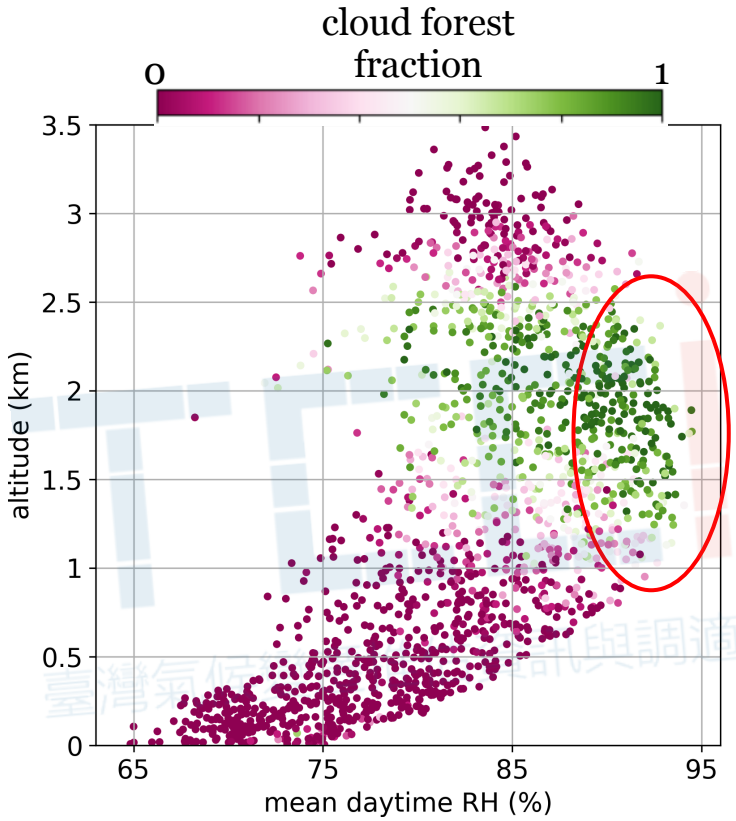
(Schulz et al. 2023)

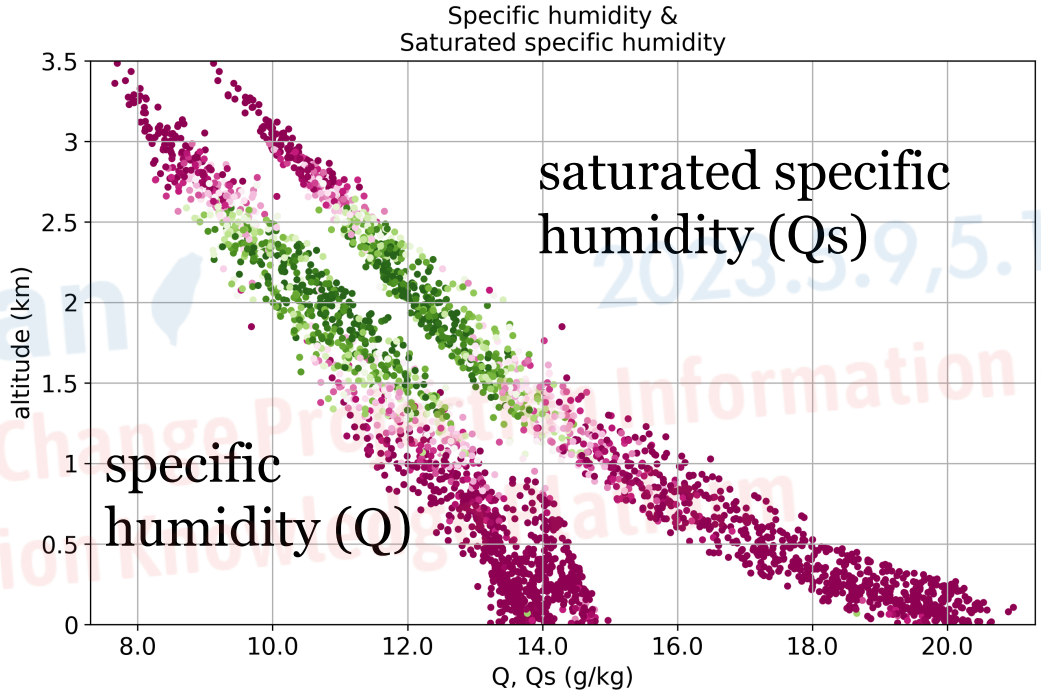
Results

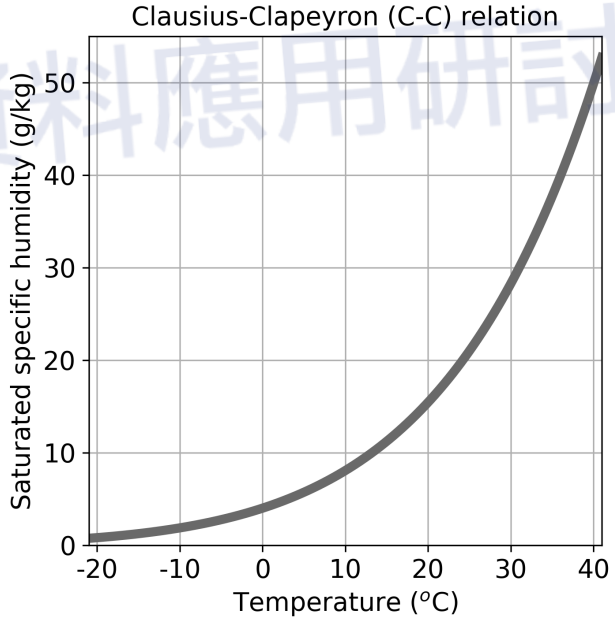




- highest daytime RH in 1000-2500m with highest cloud forest fraction







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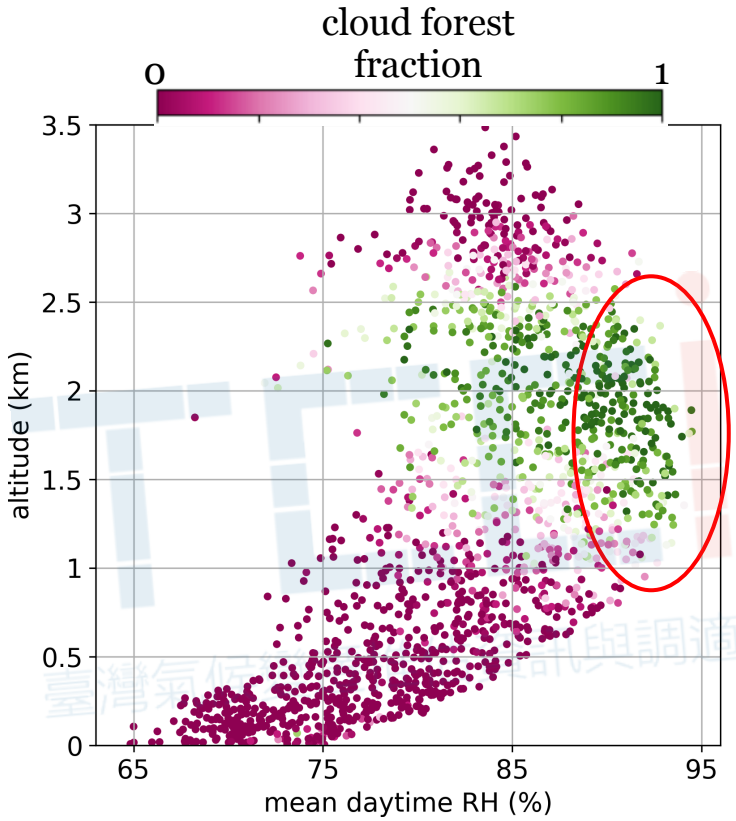
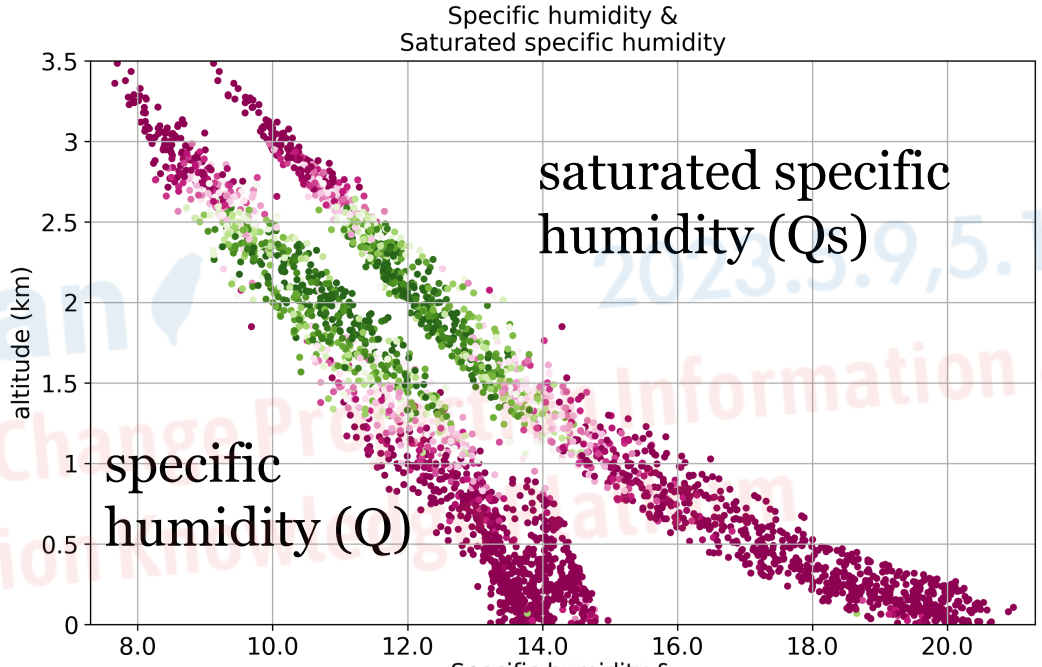
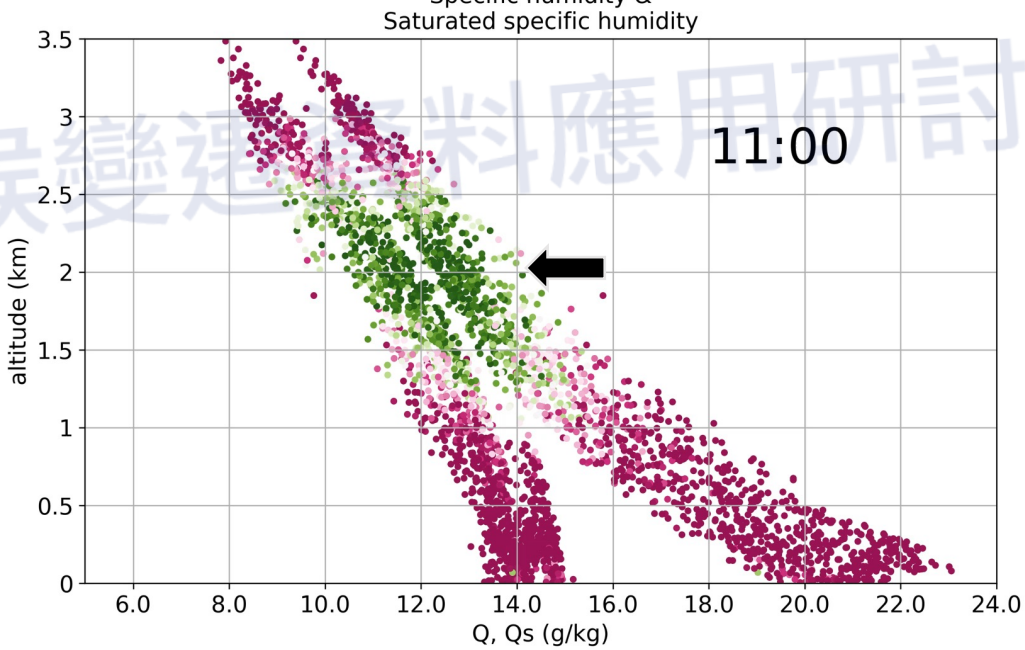
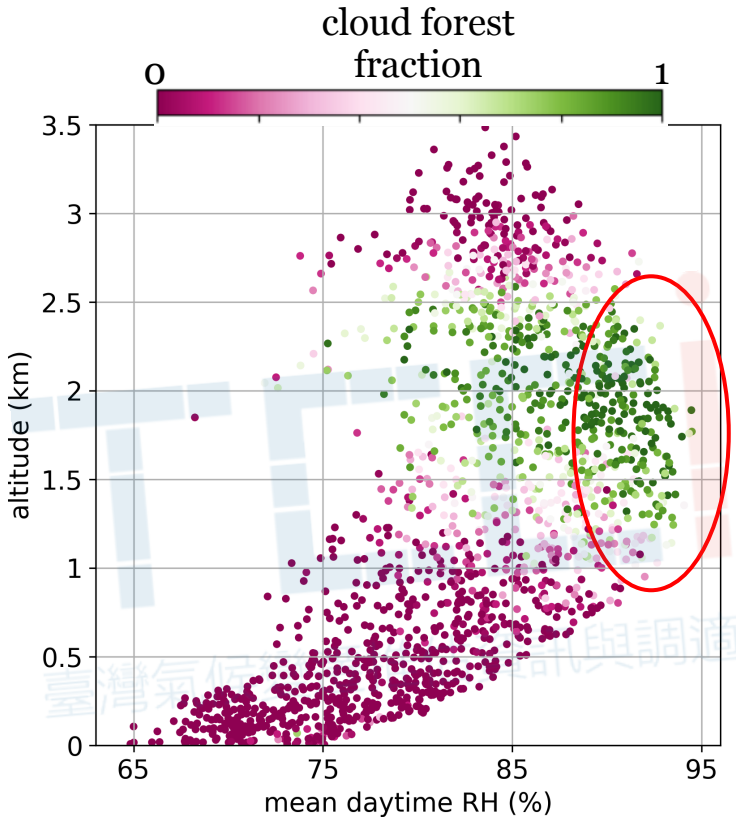
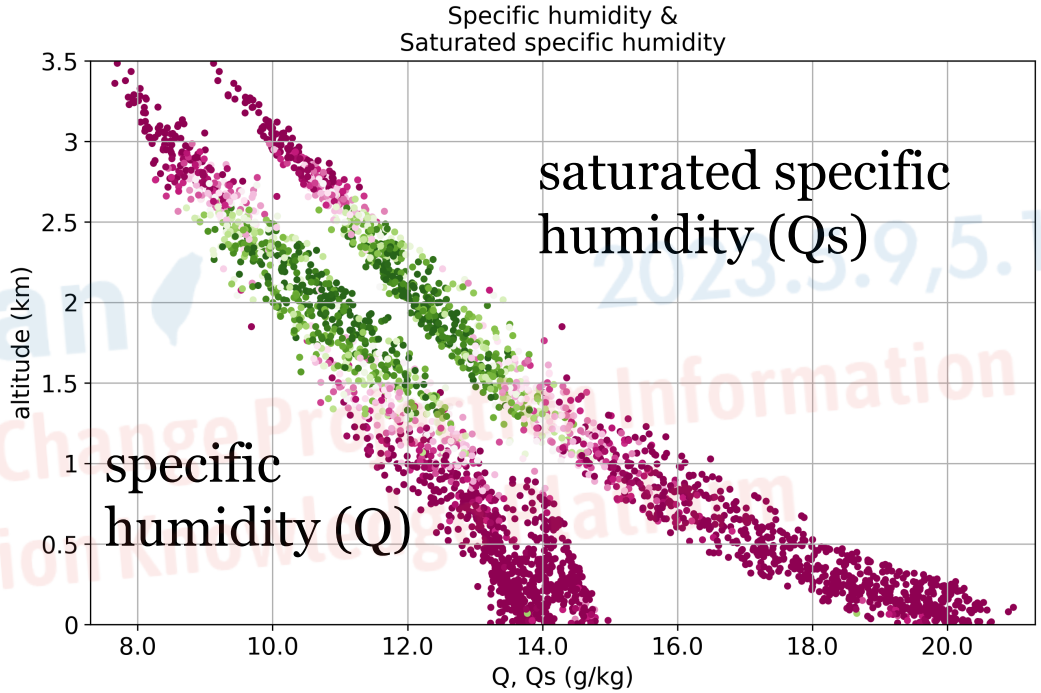






- upward concave in the midnight
- upward concave disappears at 6am
- downward concave appears at around noon
- closest value of Q and Qs in the afternoon

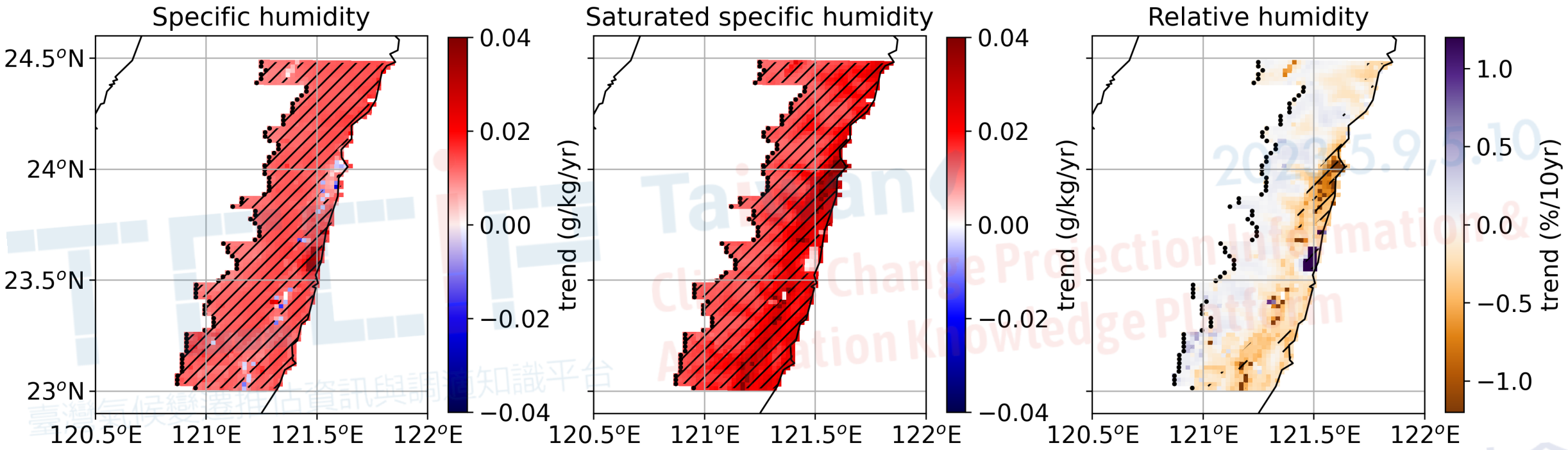




Greatest daytime RH at cloud-forest level:

1. change of Qs along height, with the effect of Clausius-Clapeyron (C-C) relation
2. great increase of Q at cloud-forest level (local and non-local supply)

mean state - - - > long term variation

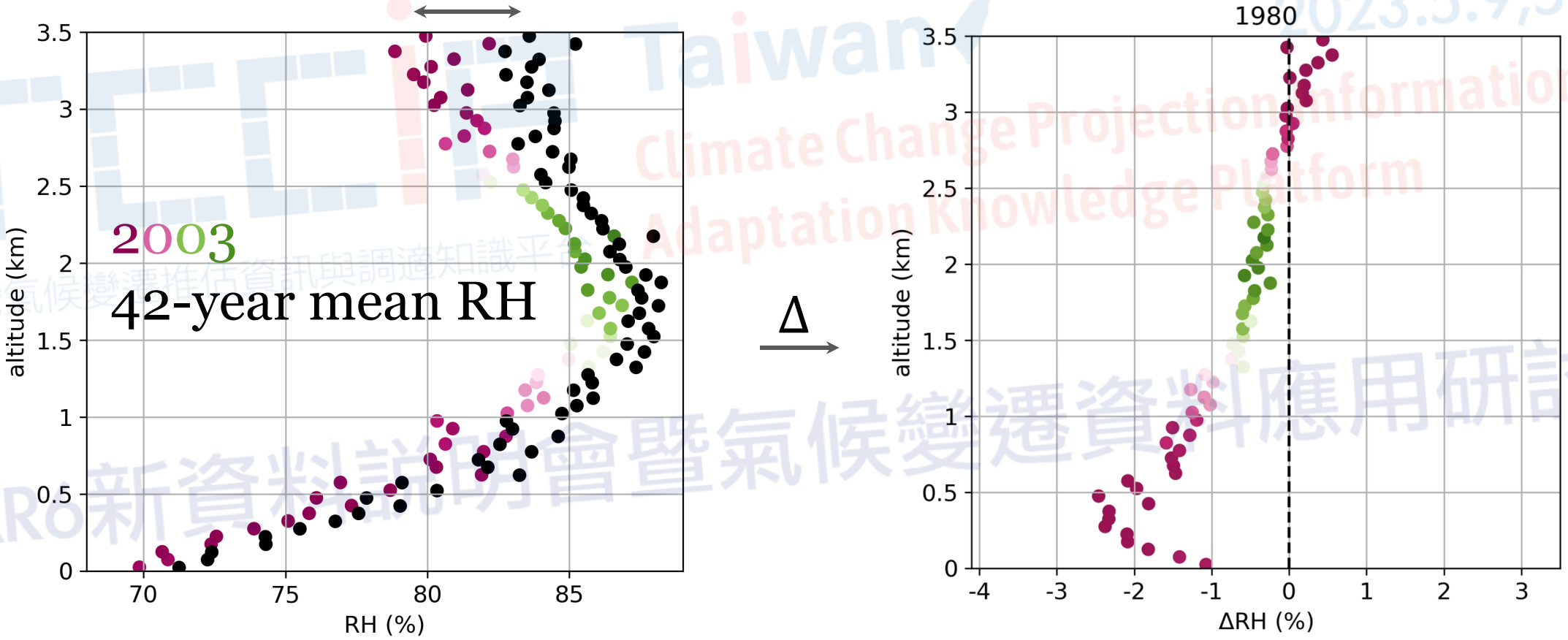


///: significant trend with P-value<0.05

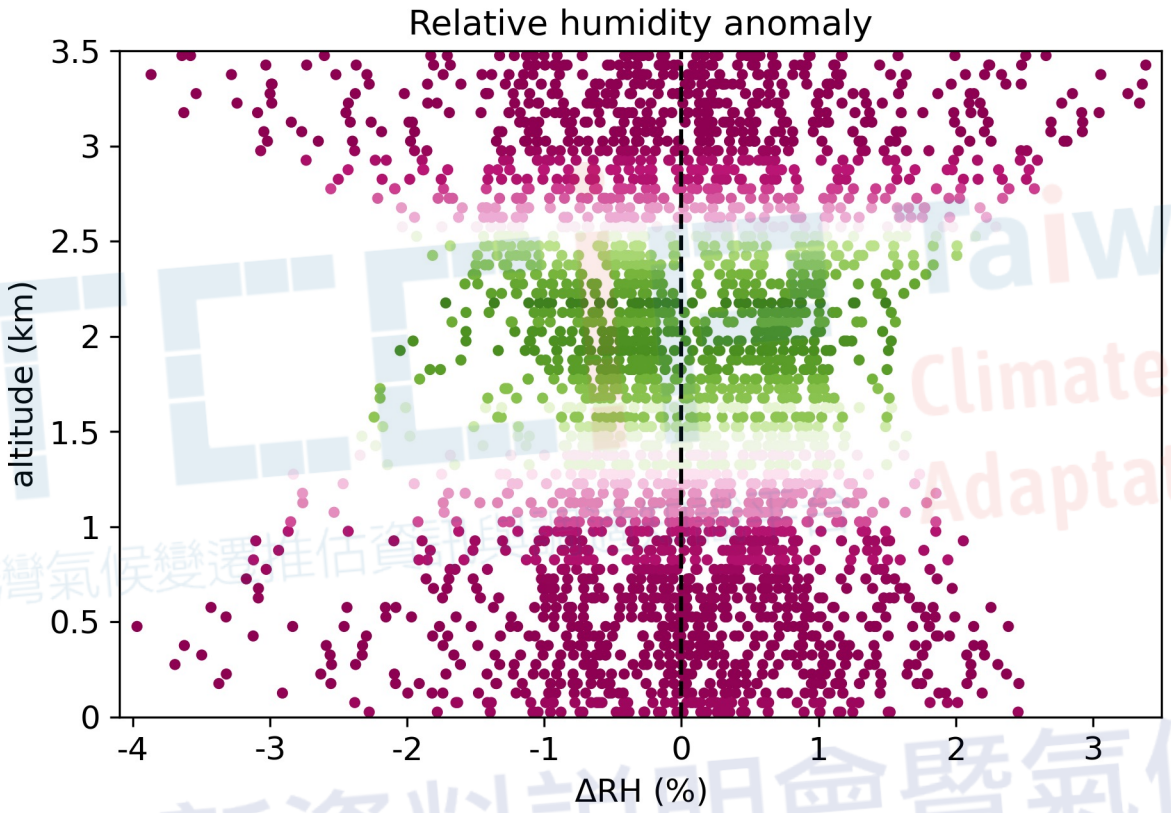
- No significant trend in daytime RH during 1980-2021

How about interannual variability?

annual RH anomaly along altitude



annual RH anomaly along altitude

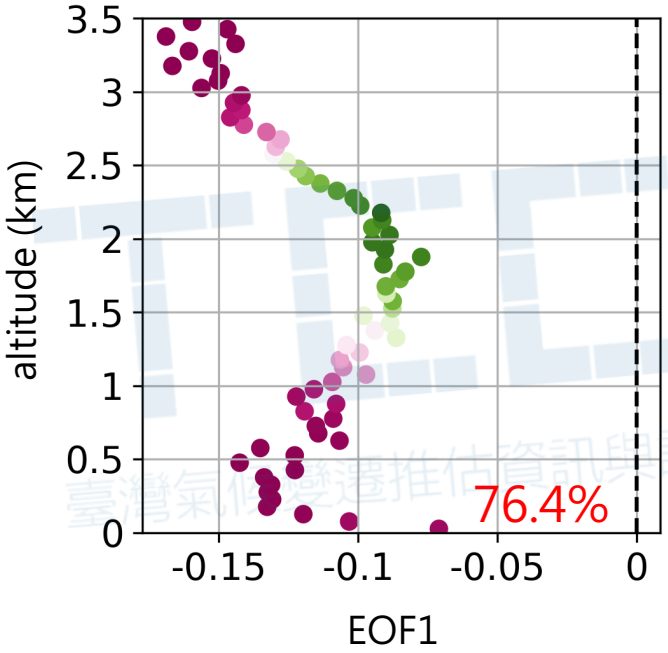


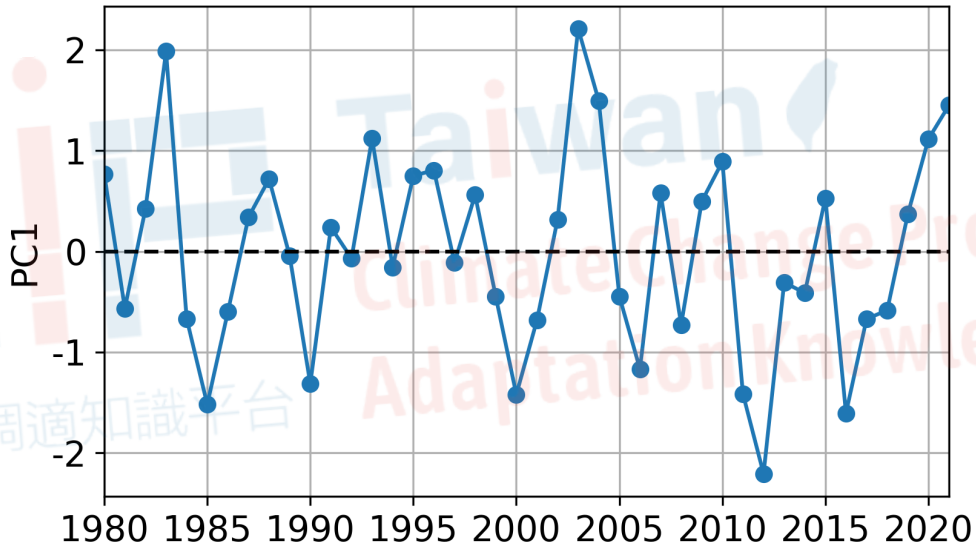
- Smaller variation of RH in cloud forests

  ⟶ Resilience in cloud forests

⟶ EOF (Empirical Orthogonal Function) analysis
(find the most dominant pattern of variability)

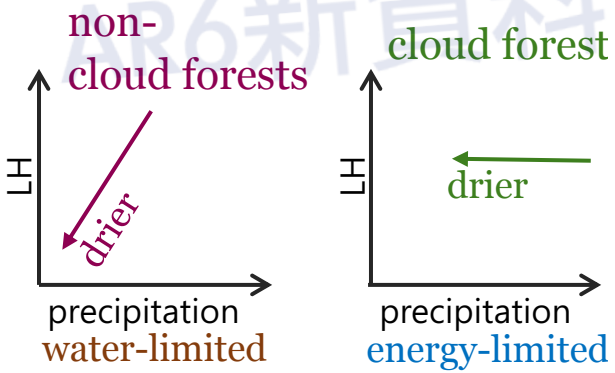
EOF analysis on annual RH anomaly along altitude





when precipitation is less, RH tends to decrease at all altitudes, with weaker decrease in the mid altitude

hypothesis:

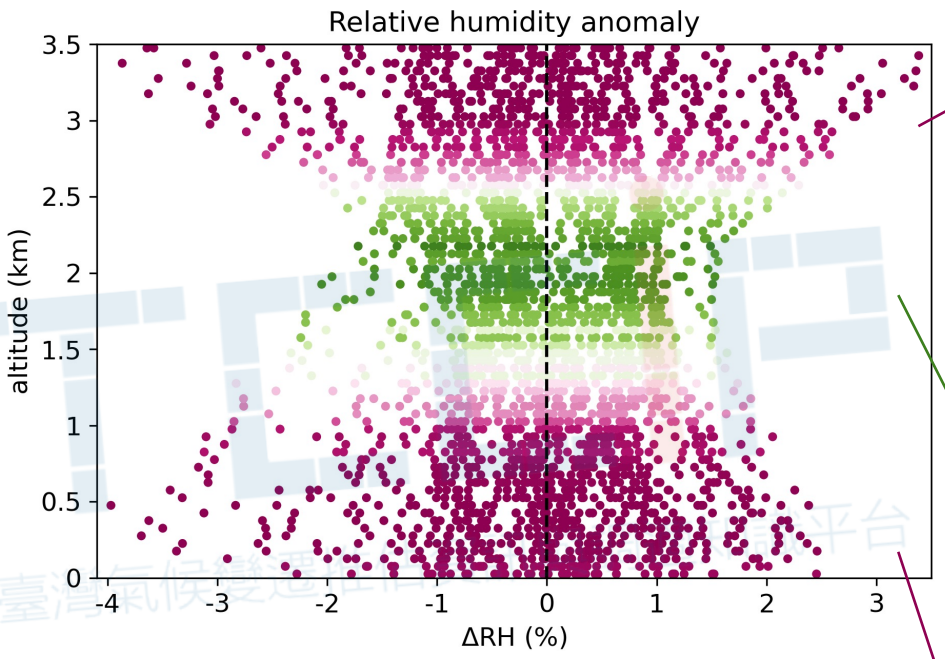


Weaker response of RH to precipitation in cloud forests:

Energy-limited condition in cloud forests?

- latent heat flux (LH) doesn't decrease much in dry years?

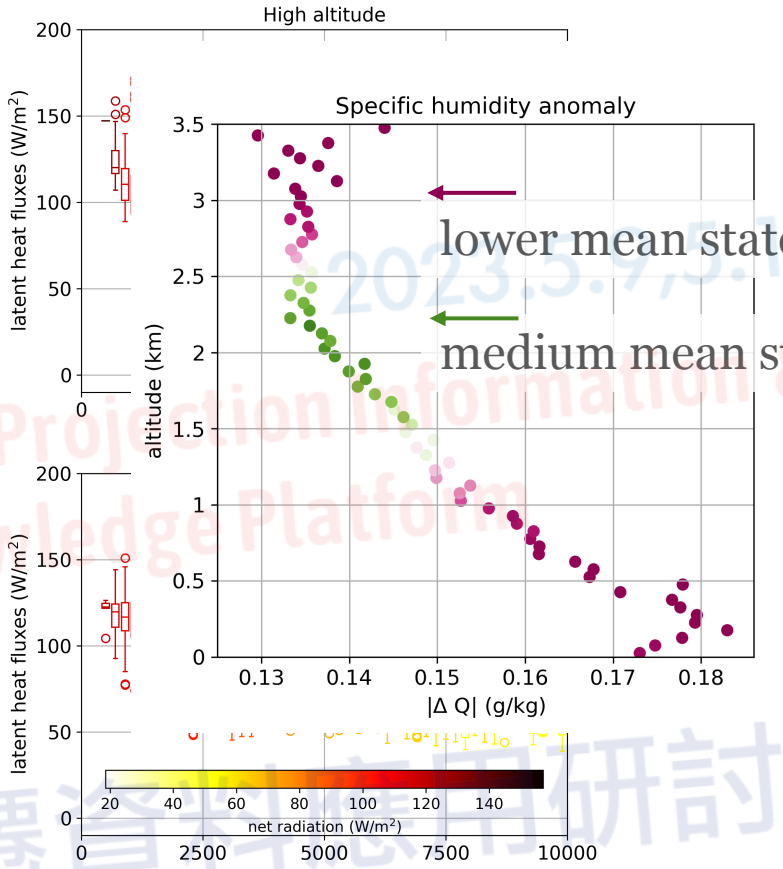
Q2. RH Long-term variation



cloud forest fraction≤0.1
high-altitude

cloud forest fraction≥0.9

cloud forest fraction≤0.1
low-altitude

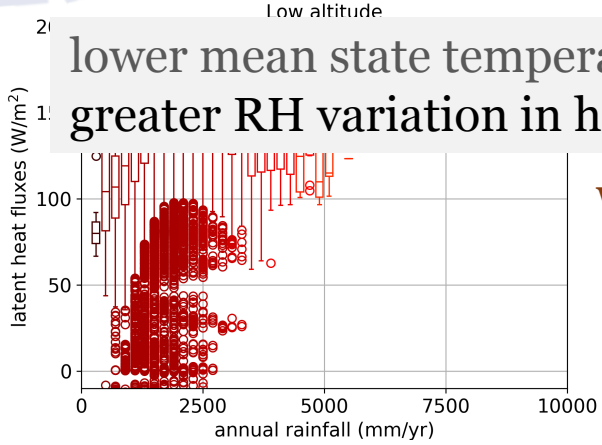


lower mean state T

medium mean state T

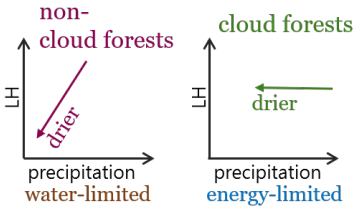
Energy-limited in high and mid altitudes:
regulated LH fluxes in wet and dry years

lower mean state temperature makes
greater RH variation in high altitudes



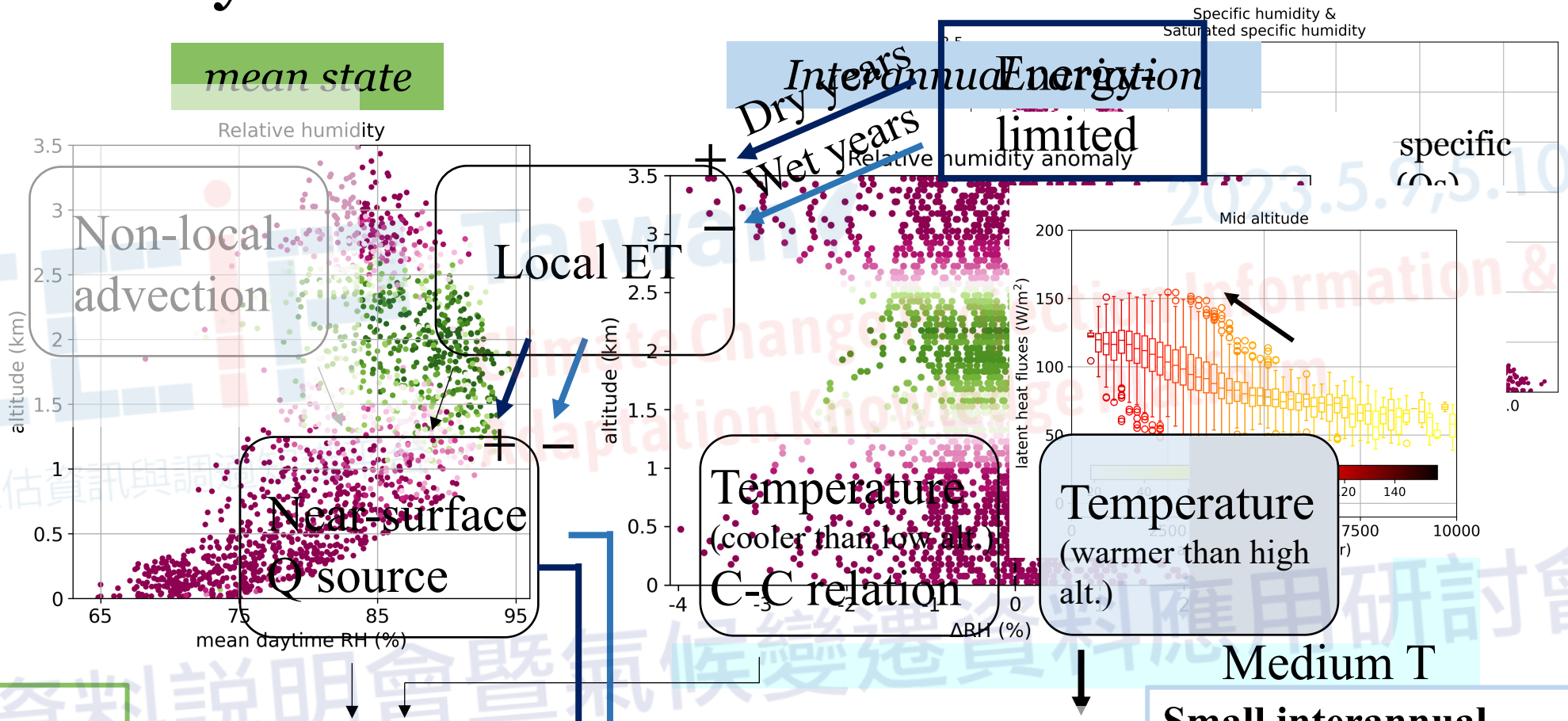
water-limited

hypothesis:



Conclusions

Relative humidity in Eastern Taiwan cloud forests



Mean state high daytime RH:

1. Daytime water vapor supply
2. Temperature with C-C relation

mean state

High daytime RH

Interannual variation

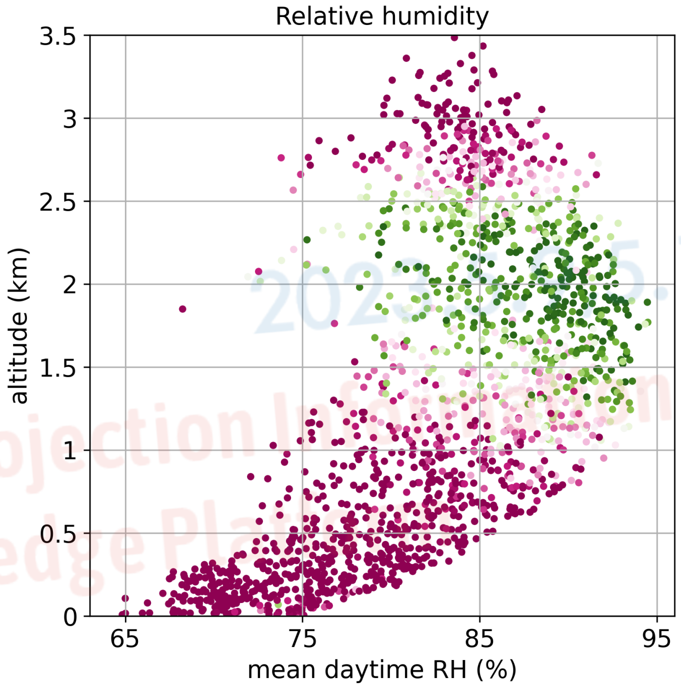
Small RH variation

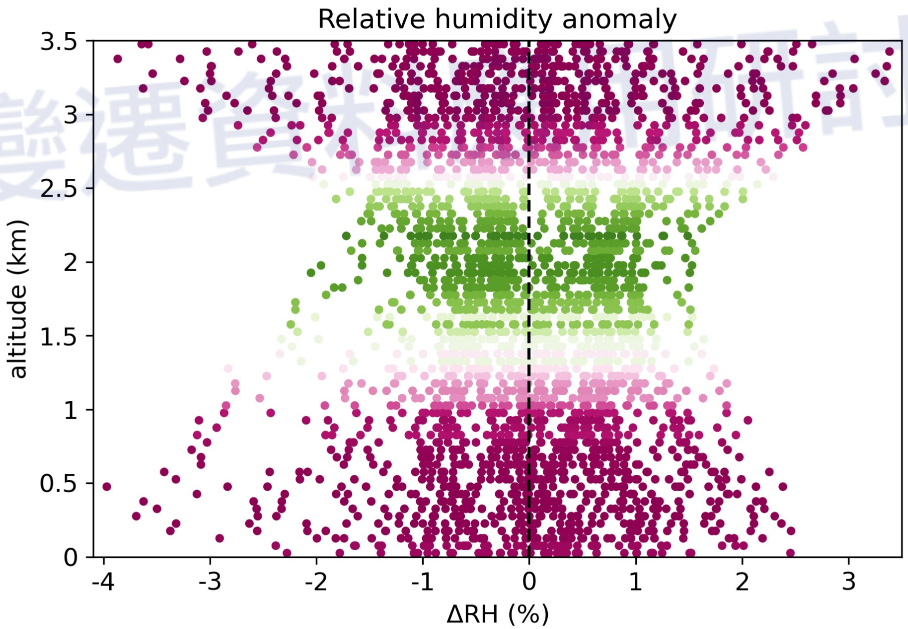
Small interannual variation of RH

1. Energy-limited condition
2. Warmer temperature than high altitude

Future work

- Responses of relative humidity in cloud forests under **future climate change**
  - Will the highest daytime RH shift to higher altitudes?
  - Can the energy-limited condition in cloud forests still regulate water vapor supply in wet/dry years?





Thank you!

Q&A

We thank Prof. Chao-Tzuen Cheng and his team for the data support of TCCIP reanalysis data. We also thank Yi-Shin Jang, Rong-Yu Gu, Prof. Cho-Ying Huang and Prof. Jehn-Yih Juang for the preliminary discussion about this research.